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## (54) Method and apparatus for production of hollowed rack bars

(57) In production of hollowed rack bars from steel tubes (3) for use in steering equipment for automobiles and so on, a part of length of the steel tube to be processed and its adjacent parts is held in split dies (5, 6) encircling a whole circumference of the tube except for the dies having a hole coinciding with the part of the tube to be processed. Then, a punch (9) is inserted into the hole at a state of the dies closed for flattening the part of the tube, and then mandrels are pushed into an inside of the tube for ironing from the inside to form a rack pattern, at a state of a rack forming die being inserted into the hole and held in contact with the flattened part of the tube (Fig.1).

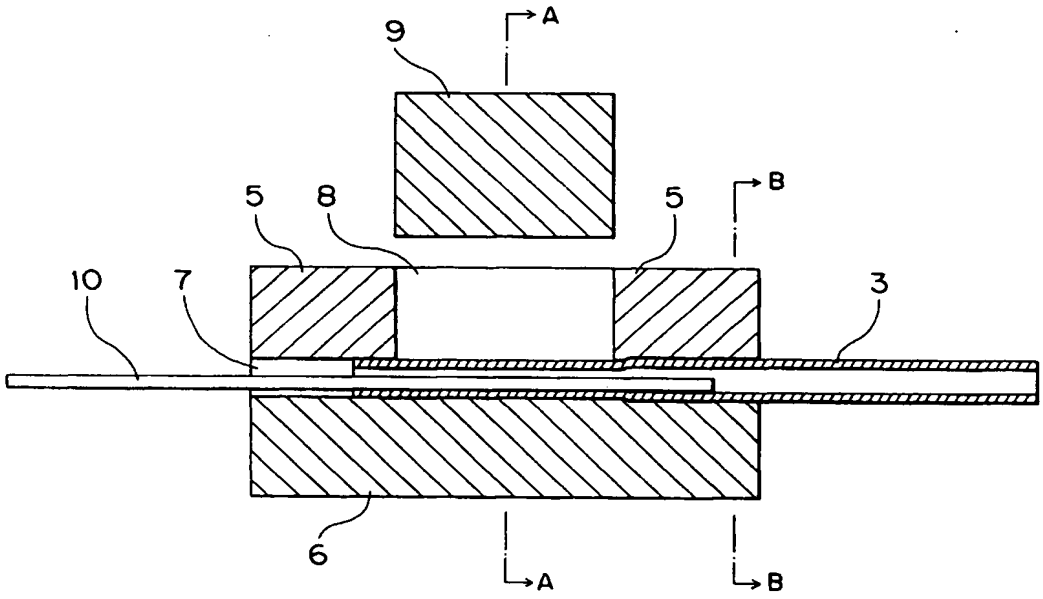


Fig. 1

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## Description

**[0001]** The present invention relates to a method and apparatus for production of rack bars that have a rack along a part of the length of bars. Rack bars are used such as components of steering equipment for automobiles. The present invention provides a method and apparatus for efficient production of hollowed rack bars by plastic working of steel tubes.

**[0002]** Conventionally rack bars for steering equipment have been made from solid bars, however, for the purpose of weight saving of automobiles, manufacturing of hollowed materials is intended. FIG. 7 is a slant view of such a rack bar 1, in which 2 indicates teeth of the rack. General method for production of such a hollowed rack bar is to drill a hole in a solid bar after cutting a rack on the surface. On the other hand, a method for forming a rack by plastic working on a steel tube material is shown in Japanese published patent 3-5892.

**[0003]** The method consists of two processing stages that is preliminarily flattening of a part of the steel tube to be formed a rack, and then forming of a rack on the flattened part. For this method, a primary-forming split dies which can be opened right and left is prepared to hold a part of steel tube to be processed, where the split die has a penetrating hole in a part to be formed a rack at a state of the dies being closed. Then, a primarily formed piece is obtained by inserting a punch having a flat top into the hole and flattening the part of steel tube. In the next place, the primarily formed piece is held in secondary-forming split dies which can be opened right and left and has an inner shape coinciding with the outer shape of a rack bar product. Namely, the secondary forming split dies have a female pattern of rack teeth in their upper part at a state of the dies being closed. Then, mandrels are inserted into the steel tube in order to perform ironing of the previously flattened part from the inside of the steel tube. Consequently, the outer surface of the primarily formed piece is bulged, and a rack is formed according to the shape of the secondary-forming split dies.

**[0004]** The above method does not waste material because of plastic forming method as compared cutting method, and can produce high quality products due to strengthening by plastic working. However, when the method is applied in practice, it has been found that there is room for further improvement because of rather high cost of dies. Namely, the primary-forming split dies are long in life because the dies are not subjected to abrasion, while the secondary-forming split dies are relatively short in life because the part of female pattern of the rack teeth is subjected to be worn out. The rack teeth pattern is not subjected to strong abrasion that deforms the intruded bulging metal, however, because of repeated large stress acting in the rack forming process, the rack teeth pattern is damaged resulting in the dies being failed by occurring cracks at bottoms of the teeth.

**[0005]** Among dies and tools for use in the above-mentioned methods for production of rack bars, short life because of abrasion in some extent will be allowed in these being subjected to friction between material such as mandrels. However, contrary to the mandrels, since the secondary-forming split dies are complex in shape in the part of rack teeth pattern and are expensive, short life of the split dies results in high cost of production of rack bars. The present invention is intended to provide an efficient method for production of rack bars by overcoming the above mentioned problems by reduction of costs of dies and tools.

**[0006]** Namely, the present invention is a method for production of a hollowed rack bar by processing a part of length of a steel tube and forming a rack thereon, the method comprising: holding the steel tube in a set of split dies, which has an inner shape of encircling a whole circumference of the steel tube at the part of length to be processed and its adjacent parts of both sides except for the dies having a hole coinciding with the part of the steel tube to be processed; inserting a punch into the hole at a state of the dies closed and flatting the part of the steel tube; inserting a rack forming die into a hole of dies with a same inner shape as aforesaid dies; holding the rack forming die in contact with the flattened part at a state of the dies closed; and inserting mandrels into an inside of the steel tube and forming a rack pattern according to the rack forming die by ironing the flattened part from the inside of the steel tube.

**[0007]** The above method may further comprise inserting a core bar into the steel tube during flattening the steel tube by the punch. Also in the above method, the punch and the rack forming die can be alternatively inserted into the hole of one set of the split dies, for flattening the steel tube and for forming the rack pattern, or otherwise, among two or more sets of the split dies with a same inner shape, one or more sets of the dies can be equipped with the punches for flattening the steel tube, and the other sets of the dies can be equipped with the rack forming dies for forming the rack pattern.

**[0008]** Moreover, the present invention is an apparatus for production of a hollowed rack bar by processing a part of length of a steel tube and forming a rack thereon, the apparatus comprising: one or two sets of split dies, which have an inner shape of encircling a whole circumference of the steel tube at the part of length to be processed and its adjacent parts of both sides except for the dies having a hole coinciding with the part of the steel tube to be processed; a punch with a flat top for inserting into the hole and flattening the steel tube; a rack forming die for holding in contact with the steel tube in the hole of the dies; and mandrels for inserting into an inside of the steel tube and forming a rack pattern according to the rack forming die by ironing the flattened part from the inside of the steel tube. Also in the above apparatus, the rack forming die may have a protruding part that is continuous in both edges at a width direction of the rack.

**[0009]** Preferred embodiments of the present inven-

tion are exemplified by means of the figures.

**[0010]** FIG. 1 is a cross-sectional view along a longitudinal direction of a rack bar explaining the method of this invention.

**[0011]** FIG. 2 and FIG. 3 are cross-sectional views perpendicular to the longitudinal direction of the rack bar at the part A-A and B-B in FIG. 1 respectively.

**[0012]** FIG. 4 is a cross-sectional view showing the next step following the process of FIG. 1 in this invention.

**[0013]** FIG. 5 is a side view of an example of a mandrel in this invention and FIG. 6 is a slant view of an example of a rack forming die in this invention.

**[0014]** FIG. 7 is a slant view showing a hollowed rack bar.

**[0015]** FIG. 1 is a cross-sectional view along a longitudinal direction of a rack bar explaining the method of this invention, and FIG. 2 and FIG. 3 are cross-sectional views perpendicular to the longitudinal direction of the rack bar at the part of A-A and B-B in FIG. 1 respectively. 5 and 6 are a set of split dies which has an inner shape of encircling a steel tube 3 to be processed and having a hole being mentioned later, when the upper and lower dies are closed. These dies are connected to an opening and shutting mechanism, which is not shown in drawings, by application of such as hydraulic cylinders. The steel tube is accommodated in the dies along the part of length to be processed, namely the part for forming a rack, and its adjacent parts of both sides. As shown in FIG. 7, because the rack is located along only one side portion of the length of the rack bar, the other side of the length of the steel tube is outside of the dies, when the tube is accommodated in the dies. Namely, the split dies can be closed at the part of one end of the tube material, however, as will be mentioned later, it is favorable that the split dies in the closed position have a hole 7 at the extension of the tube so as the hole to be lead to the pipe, because of convenience for inserting mandrels into the tube. Besides, it is natural that the set of split dies can be composed of three or more dies contrary to the two of the upper and lower dies as shown in FIG. 1 and so on.

**[0016]** As mentioned above, the split dies 5 and 6 have a shape of encircling the whole circumference of the steel tube 3, however, at an area coinciding with a part of the tube to be processed, the dies have a hole which extends perpendicular to the axis of tube. Namely, 8 in FIG. 1 and FIG. 2 is a hole in the upper die, wherein the hole has a rectangular shape coinciding with the part to be formed a rack. After the steel tube is held in the split dies as mentioned above, a punch 9 with a flat top is inserted into the hole 8 for pressing this part of the steel tube 3 to form a flat surface thereon. The punch 9 is connected to a pressing mechanism, which is not shown in drawings, by application of such as hydraulic cylinders, and has preferably a section to fill just the rectangular hole without space. During the pressing operation the interior of the tube material may be empty, however, a core bar 10 may be inserted that has a cross section coinciding with a inner shape of the flattened tube which is a segmented circle, as shown in FIG. 1 and FIG. 2. Presence of the core bar enables controlling of thickness and cross-sectional shape of the flattened part by pressing between the punch and the core bar. A series of plastic working in this invention, including this flattening, can be performed as cold working, however, naturally can be performed as hot working by heating the workpieces to high temperatures.

**[0017]** FIG. 4 is a cross-sectional view of the same position as shown in FIG. 1, explaining the following process. As shown in this drawing, a rack forming die 11 is inserted into the hole 8 in the upper die 5 of the split dies in place of aforesaid punch 9, and is held in contact with aforesaid flattened part of steel tube 3. In this alignment a mandrel 12 is pushed into the tube to form a rack on the tube according to the rack forming die 11 by ironing the flattened part from inside of the tube. The rack forming die has a same shape as the punch 9 used for flattening in the preceding process except for a female pattern of rack teeth on the top, and has a cross section to fill just the hole of the split dies. Therefore, by keeping the tube material in the same split dies 5 and 6, aforesaid punch 9 can be exchanged to the rack forming die 11. Naturally, after performed the flattening process by the punch for plural tube materials, the rack forming process can be performed for those plural tube materials by replacing the punch with the rack forming die. Thus, in the method of this invention, the rack forming die alone with short life can be exchanged.

**[0018]** Moreover in large scale production, the split dies combined with the punch and the split dies combined with the rack forming die can be made exclusive use respectively, then the process can be performed by transferring workpieces between them. Naturally, it is not necessary to be equipped with mandrels and their pushing mechanism for the split dies combined with the punch, wherein the process for flattening of steel tubes is exclusively performed. On the other hand, for the split dies exclusively combined with the rack-forming die, the rack-forming die can be fixed to one of the split dies such as the upper die. Even in this case the advantage is not lost that the rack forming die alone can be exchanged.

**[0019]** The mandrel is inserted into the steel tube by installed to a pressing mechanism not shown in drawings. Insertion into either side of the tube does not give different effects in principle as plastic working, however, insertion from the side near the part to be formed a rack can make the mandrel shorter. For this purpose, as mentioned before referring FIG. 1, the split dies 5, 6 in the closed position should have a hole 7 at the extension of the steel tube so as the hole to be led to the tube. Moreover, by inserting mandrels alternatively from both ends, working time can be saved.

**[0020]** Ironing process by insertion of mandrels can be carried out at room temperature, however, shaping

of a rack in a single step is impossible and the rack teeth should be formed in multiple steps by inserting mandrels of incremental sizes. For this purpose, by use of a mandrel as shown a side view in FIG. 5, which has a plural steps 14 of incremental sizes at the position of ironing, the number of strokes can be reduced. Further, the mandrel can have a shape that the positions of ironing rise in lump-shape from the other part. Namely the mandrel having a series of lump with incremental height can bring same performance as the mandrel with multiple steps as shown in FIG. 5. Sufficient lubrication such as feeding of oil during insertion of mandrels can reduce abrasion of mandrels and decrease force for working.

**[0021]** The present invention can produce hollowed rack bars in a series of working operation mentioned above. In the apparatus disclosed in afore-mentioned Japanese published patent 3-5892 , because the split die and the rack teeth are combined in one body, the whole body must be replaced when the part of teeth is damaged. Contrarily, in the apparatus of this invention, only the part of the rack forming die which is subjected to heavy abrasion is enough to be replaced. Moreover, the split dies combined with the pattern of rack teeth are difficult to make because of complicated form, but the rack forming die according to this invention has relatively simple form that is easy to make. Therefore, the cost for the dies is low in this invention.

**[0022]** Moreover, it has been proved that life of the rack forming die can be elongated by optimization of the die form in the apparatus for production of rack bars according to this invention. Namely, for the rack forming die according to this invention, it may be thought to be common that the female pattern of the rack teeth is shaped through the whole width to have a same sectional form, when cut at any position parallel to the longitudinal direction of the rack forming die. The rack forming die of such a form can be made easily by grooving with milling cutter. However, it has been proved that the life of the rack forming die is significantly improved by shaping the die, as shown in the slant view of FIG. 6, to have a protruding part 16 that is continuous in both edges at the width direction of the rack. By this configuration, the tops 15 of the teeth on the rack forming die, namely, the part corresponding to bottoms of teeth of a rack to be formed, are continued in both edges at the width direction of the rack.

**[0023]** That is, failure mode at the end of life of a rack forming die is characterized by appearance of cracks at the bottoms of teeth of the die, namely at the part corresponding to the tops of teeth of a rack to be formed. This is thought to be a result of stress to bend the teeth of the rack die, when the metal bulging from the flattened part of the tube is blocked by the rack forming die. Consequently, as a result of the stress being concentrated to the bottom of concave place of the die, it is presumed that the ultimate strength of that part cannot endure the stress and the cracks are lead to initiate. The reason for designing the rack forming die, wherein the tops 15 of the teeth are continued in both edges at the width direction of the rack, is based on this consideration. By this configuration, the stress to bend the teeth of the rack forming die does not concentrate to the bottoms 17 of concave place on the die, but is dispersed in the continuous protruding part. Thus crack initiation at the bottoms of concave place on the rack forming die is prevented, leading to long life of the die. Besides, in use of the rack forming die wherein the protruding part is continuous in the edges at the width direction of the rack, width of rack teeth being formed is smaller than in use of the rack forming die with female pattern of the teeth throughout the width, if sizes of the split dies and other tools are same. However, this is not a problem in practice of designing rack bars.

**[0024]** The present invention should not be limited to the embodiment as explained above with reference to the drawings. The present invention can be modified or improved appropriately in practice without loss of the effectiveness within the technological concepts and features of the present invention. For example, in case of flattening a part of outer surface of a steel tube, deformations from a simple flatness should be included within the scope of the present invention, so long as it does not deviate from spirit of this invention. Similarly, in some cases the surface of a mandrel to be countered to the inner surface of the flattened part of a steel tube, may be deformed from a simple flatness.

## Claims

1. A method for production of a hollowed rack bar by processing a part of length of a steel tube and forming a rack thereon, characterized by the method comprising: holding the steel tube in a set of split dies, which has an inner shape of encircling a whole circumference of the steel tube at the part of length to be processed and its adjacent parts of both sides except for the dies having a hole coinciding with the part of the steel tube to be processed; inserting a punch into the hole at a state of the dies closed and flatting said part of the steel tube; inserting a rack forming die into a hole of dies with a same inner shape as aforesaid dies; holding the rack forming die in contact with the flattened part at a state of the dies closed; and inserting mandrels into an inside of the steel tube and forming a rack pattern according to the rack forming die by ironing the flattened part from the inside of the steel tube.

2. The method as claimed in claim 1, characterized by further comprising inserting a core bar into the steel tube during flattening the steel tube by the punch.

3. The method as claimed in claim 1 or 2, wherein the punch and the rack forming die are alternatively inserted into the hole of one set of the split dies, for

flattening the steel tube and for forming the rack pattern.

4. The method as claimed in claims 1 or 2, wherein among two or more sets of the split dies with a same inner shape, one or more sets of said dies are equipped with the punches for flattening the steel tube, and the other sets of said dies are equipped with the rack forming dies for forming the rack pattern.

5. An apparatus for production of a hollowed rack bar by processing a part of length of a steel tube and forming a rack thereon, characterized by the apparatus comprising: one or two sets of split dies (5,6), which have an inner shape of encircling a whole circumference of the steel tube at the part of length to be processed and its adjacent parts of both sides except for the dies having a hole (8) coinciding with the part of the steel tube to be processed; a punch (9) with a flat top for inserting into the hole (8) and flattening the steel tube; a rack forming die (11) for holding in contact with the steel tube in the hole (8) of the dies; and mandrels (12) for inserting into an inside of the steel tube and forming a rack pattern according to the rack forming die (11) by ironing the flattened part from the inside of the steel tube.

6. The apparatus as claimed in claim 5, wherein the rack forming die has a protruding part (16) that is continuous in both edges at a width direction of the rack.

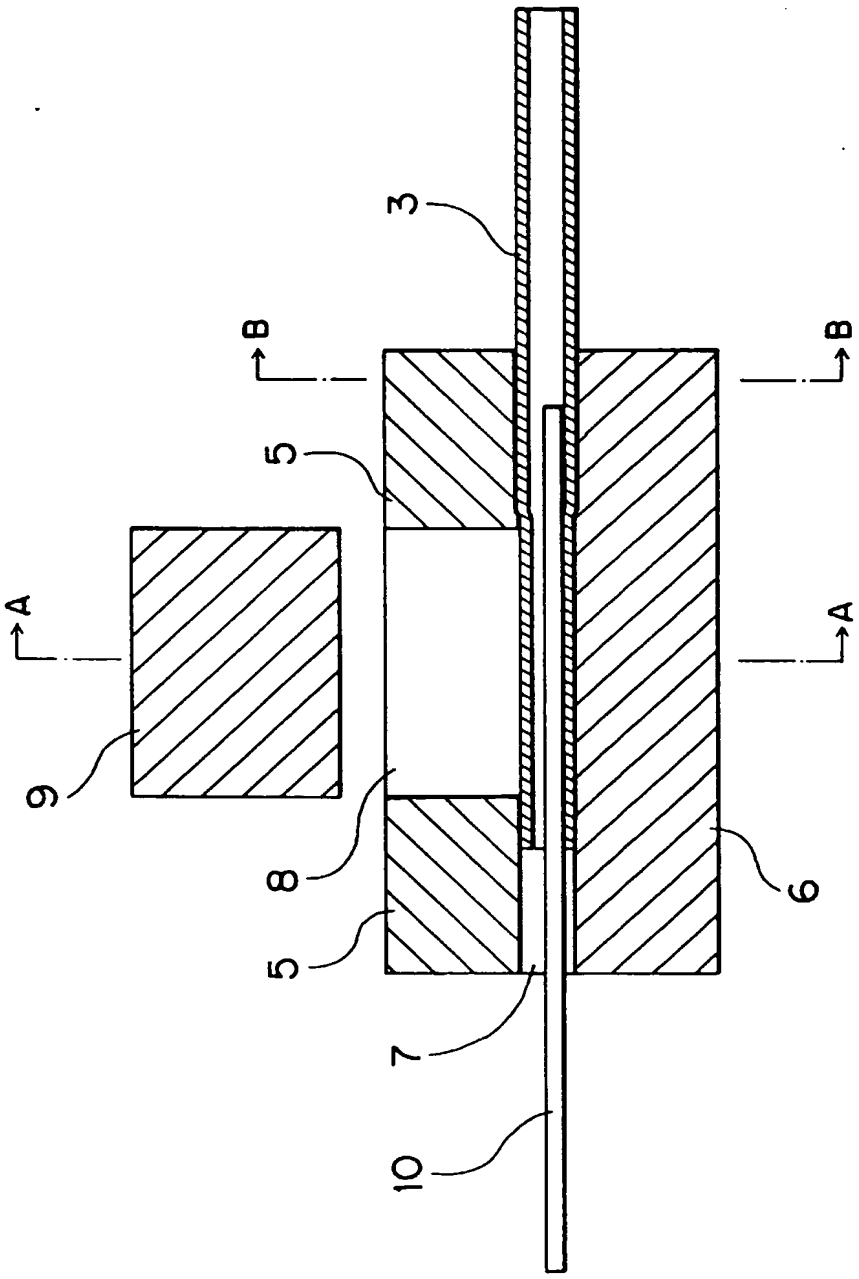


Fig. 1

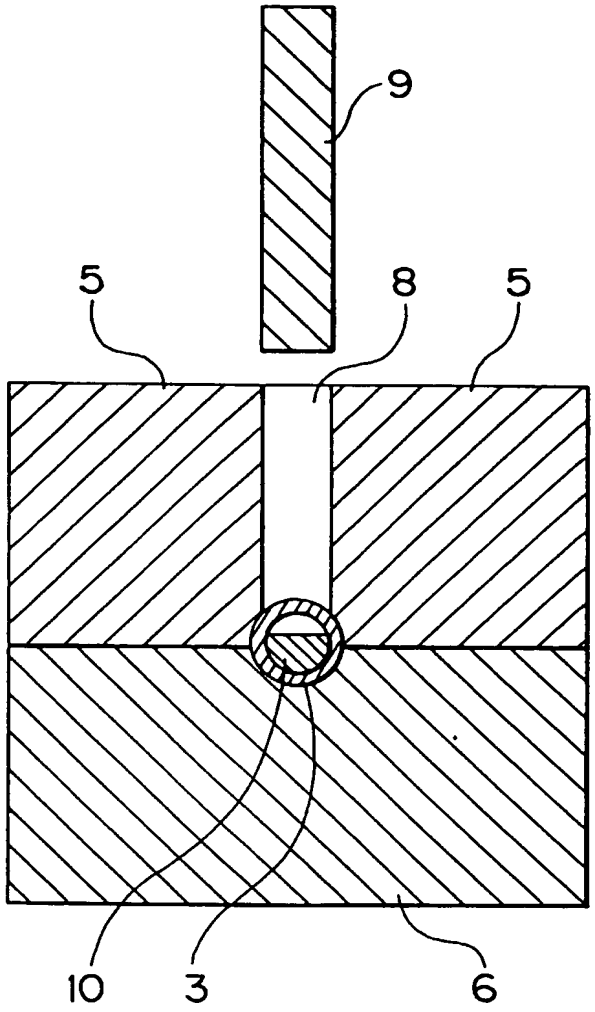


Fig. 2

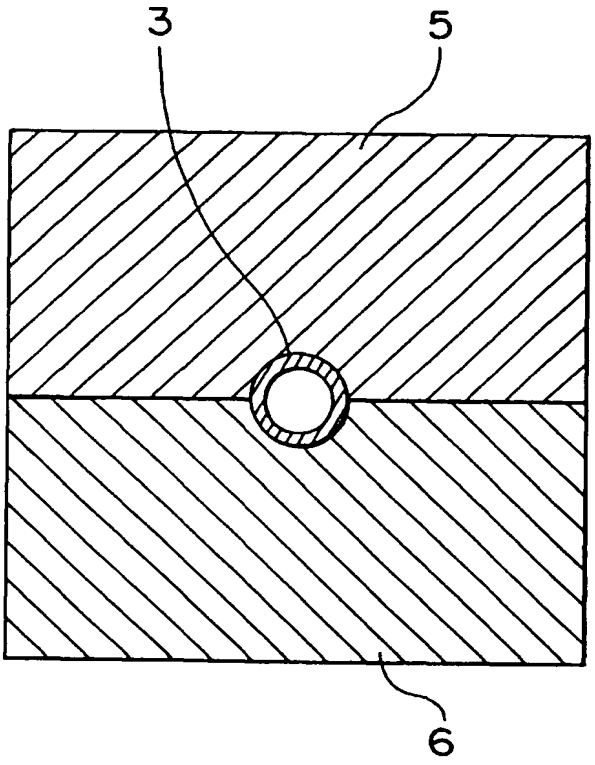


Fig. 3

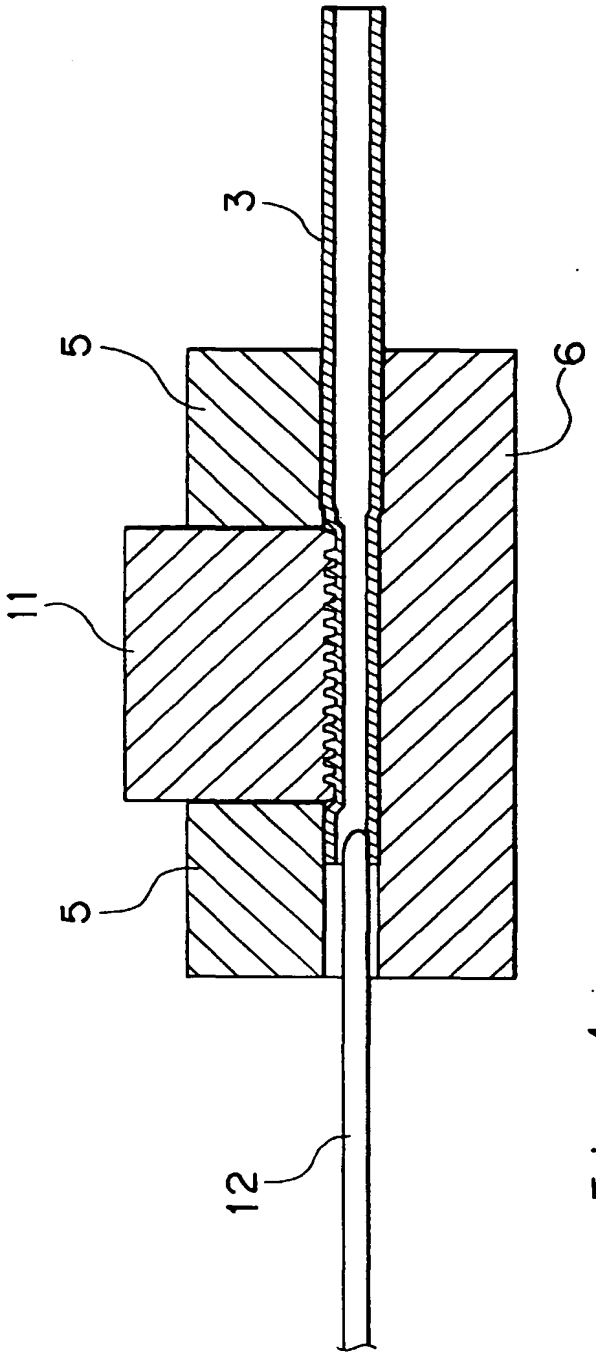


Fig. 4

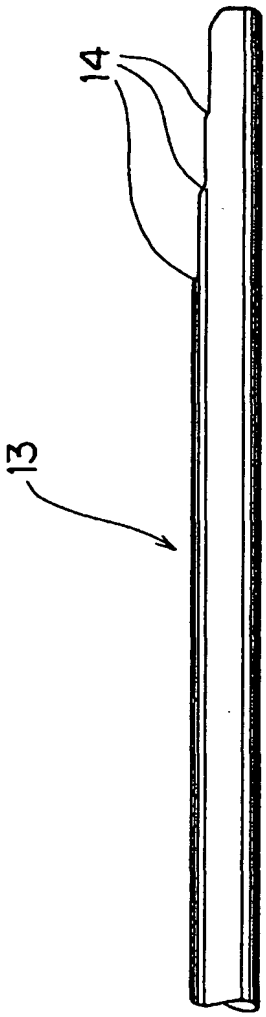


Fig. 5

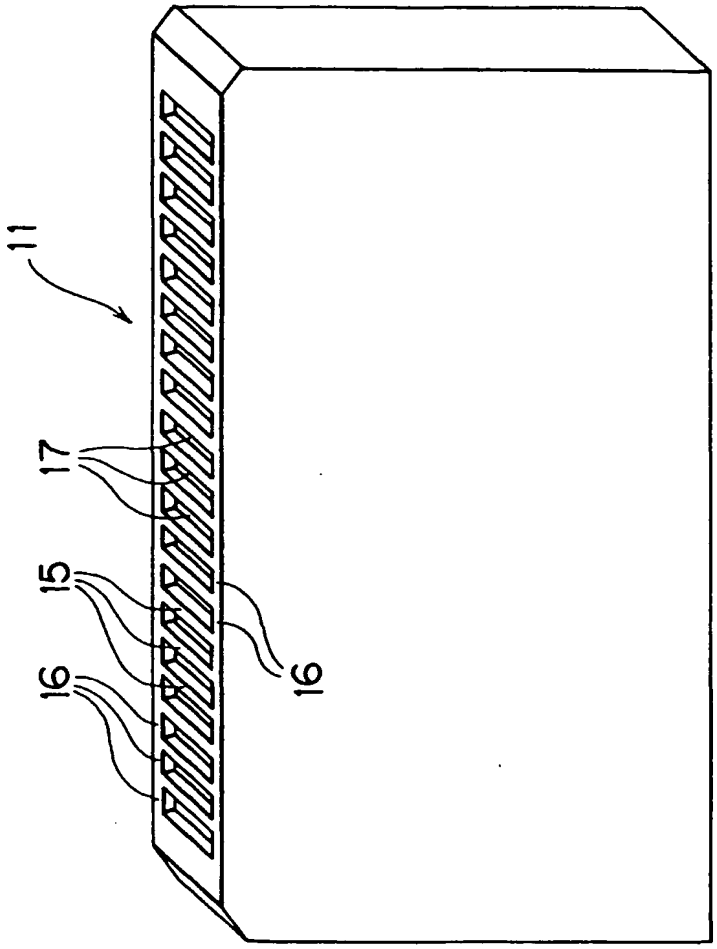


Fig. 6

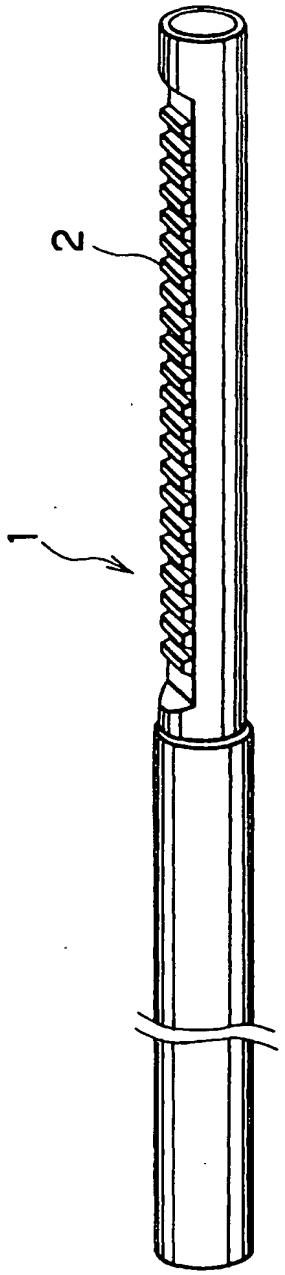


Fig. 7